

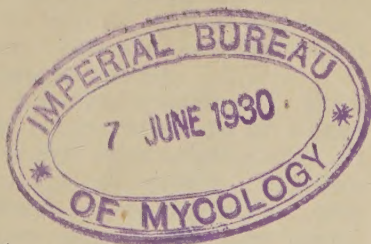
The Effect of Dusting-Sulfur upon the Germination of the Pollen and the Set of Fruit of the Apple

L. H. MacDaniels and J. R. Furr



VIGOROUS APPLE SPUR WITH FOUR YOUNG FRUITS

In this so-called spur-unit method the effect of different treatments of the flower is compared on the same spur



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THE EFFECT OF DUSTING-SULFUR UPON THE GERMINATION OF THE POLLEN AND THE SET OF FRUIT OF THE APPLE

L. H. MACDANIELS AND J. R. FURR

In some sections of New York and New England sulfur dust is applied to apple trees during the blossoming period for the control of apple scab. There are many instances where this practice has been followed without noticeably reducing the crop. Inasmuch, however, as there has been no carefully checked experimental work done on this specific problem, it is not certain just what the effect of dusting the trees while in bloom has been on the set of fruit or under what conditions the application of sulfur dust on the bloom might be detrimental.

The purpose of the present investigation is first, to determine the effect of sulfur on the germination of apple pollen in artificial media; secondly, to determine the effect on the set of fruit of the application of sulfur to the stigmas of the blossoms at different times, with reference to the time of hand-pollination; and thirdly, to determine the effect on the set of fruit of applying sulfur under field conditions.

PREVIOUS INVESTIGATIONS

A similar problem was investigated by Bailey (Beach and Bailey, 1900) in which the effect of spraying trees in bloom with bordeaux mixture and arsenicals was tested in the field, and by Beach (Beach and Bailey, 1900) who carried on more carefully controlled experiments in the laboratory to determine the effect of bordeaux mixture on pollen germination in sugar solutions and upon the set of fruit with selected blossoms on the tree.

In the light of our present knowledge of apple scab, the field experiments reported by Bailey are inconclusive with regard to the effect of spraying the blossoms on the set of fruit. The trees were sprayed only once, so that in seasons when scab infestation was severe the crop was greatly reduced on the trees that received no protective spray until the calyx application. In such seasons, trees sprayed during the blooming period actually showed in some instances an increase in yield and better fruit when compared with those sprayed later. They showed no significant difference from those sprayed before the blossoms opened.

The experiments of Beach showed that a bordeaux mixture (1 gram of copper sulfate, 0.75 gram of lime, 100 cubic centimeters of water) diluted to five parts per thousand with 2-per-cent sugar solution inhibited or greatly reduced pollen germination and pollen-tube growth. Blossoms sprayed during early bloom with a bordeaux mixture combined with arsenite of copper failed to set fruit. Trees sprayed only once during the blooming season with bordeaux mixture and arsenite of copper had their crop reduced from 8 to 10 per cent, and trees sprayed every day during the bloom failed to set a satisfactory crop.

Anderson (1914) conducted experiments showing that dust from a cement mill applied to the stigmas of the blossoms of apples, pears, sweet

cherries, and sour cherries prevented fruit from setting or greatly reduced the crop. He found also that very dilute solutions of the cement dust prevented the germination and the growth of apple pollen, presumably because of the toxicity of the soluble calcium salts contained.

Some information regarding the effect on the set of fruit of spraying fruit trees while in bloom with fungicides has been obtained by different workers incidental to the study of the control of fire blight. McCue (1917) sprayed five blossoming Bartlett pear trees with a 4-6-50 bordeaux mixture. His data show that on the sprayed trees only 4.4 per cent of the blossoming spurs held mature fruit; whereas on the unsprayed trees, 16.6 per cent of the blossoming spurs held fruit at harvest. His conclusion was that "serious injury may be done to the set of fruit by spraying in bloom."

Stevens and others (1917) sprayed two Kieffer pear trees while in bloom with a 4-4-50 bordeaux mixture. One tree was sprayed every day during the blooming period and the other on alternate days. It is stated that the trees showed no reduction in the set of fruit. However, lime sulfur, summer strength, or "1 to 24 homemade," applied on the same days "damaged the flowers and cut down the set." No data on the set of fruit are given.

McCown (1929) sprayed apple trees just as they were coming into bloom and again while in full bloom with a 1-3-50 bordeaux mixture. It is stated that there was no reduction in fruiting, but no data are given on this point.

METHODS AND RESULTS

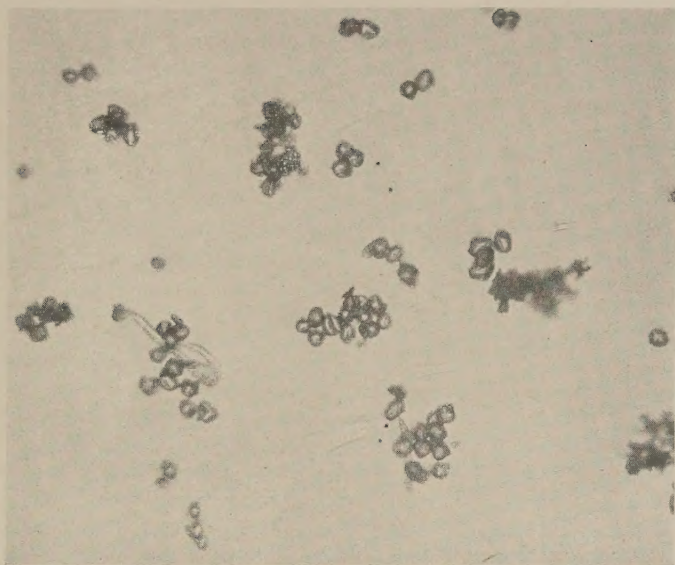
The results of the effect of sulfur on the germination of different varieties of apple pollen on agar media are given in table I. Of several

TABLE I. EFFECT OF SULFUR UPON THE GERMINATION OF POLLEN ON AGAR MEDIA*

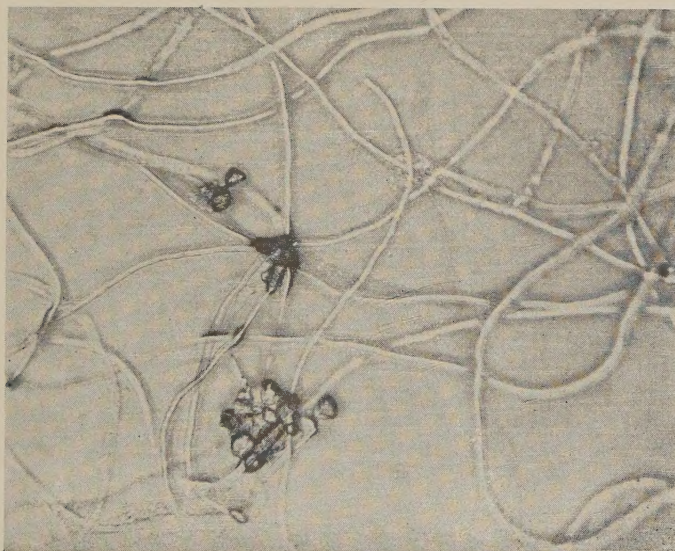
Variety of pollen	Per cent of germination	
	Without sulfur	With sulfur
Delicious		
Lot 1.....	60	1
Lot 2.....	80	15
Northern Spy.....	70	15
Rome.....	50	1
Wealthy.....	30	1
McIntosh.....	50	20
Tolman Sweet.....	75	1

* Figures given are careful estimates but not accurate counts.

different combinations of nutrient solutions and types of agar, the best germination was obtained by using 1½ grams of agar shreds, 10 grams of commercial cane sugar, and 100 cubic centimeters of distilled water. Bacto agar, tap water, or weak Knopf solution reduced germination and growth. In the tests, the surfaces of the agar in the petri dishes were divided in half and pollen from the same source was placed on each side. On one side sulfur was dusted with a camel's-hair brush so that the grains of sulfur lodged among the pollen grains. In every case the percentage of germination was greatly decreased or nearly inhibited by the presence



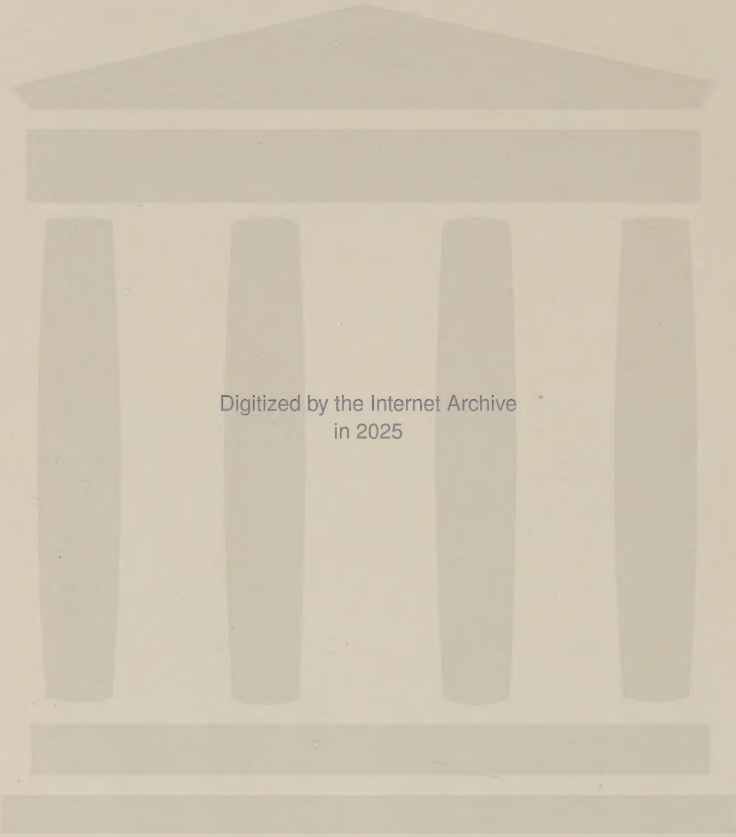
A



B

EFFECT OF DUSTING-SULFUR UPON THE GERMINATION OF APPLE POLLEN
ON SUGAR-AGAR MEDIA

A, Pollen germination inhibited by presence of sulfur. B, Check, good germination and pollen-tube growth on another part of the same petri dish used in A; no sulfur was applied



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of the sulfur. This is illustrated in Plate I, which shows results obtained on the two halves of the petri dish. The grains that did grow on the side treated with sulfur averaged shorter germ tubes than did those on the side where no sulfur was applied.

In another test, pollen grains were sown in drops of 10-per-cent sugar solution on glass slides and 300-mesh dusting sulfur was scattered over the surface of the drops. The slides were then placed in petri dishes. In these cultures the pollen grains germinated normally, there being no appreciable difference between the slides with sulfur and the checks. That no inhibition of germination occurred was apparently due to the fact that the sulfur remained on the surface film of the drop, whereas the pollen sank to the surface of the slide and hence was not in contact with the sulfur. The sulfur not being soluble produced no effect upon the germinating pollen grains at that distance.

In this work it is evident that in order to get the inhibiting effect of the sulfur upon the germination and the growth of pollen, the sulfur must either be touching the pollen grain or must be very close to it. This observation is in line with the work of Goodwin and Salmon (1927) who found that sulfur had little effect on the growth of the hop-mildew fungus unless the sulfur particles were in contact with the fungus. The similarity between germinating pollen grains and the germinating spores of some fungi has already been pointed out (Beach and Bailey, 1900). The apparent structure of the walls and germ tubes and the nature of germination and growth are so nearly alike that similar reaction to fungicides is not surprising. The way in which sulfur inhibits spore germination and growth is a controversial subject which it is not the purpose of this bulletin to consider.

The results of experiments carried on to determine the effect of sulfur applied to the stigmas of blossoms upon the set of fruit are given in table 2. In this experiment the flowers on vigorous spurs were thinned to two and were covered with glassine bags. In all series both flowers on each spur received pollen but only one of these was treated with sulfur. In series 1, the pollen and the sulfur were applied at the same time. In series 2, the sulfur was put on the day preceding pollination. In series 3, sulfur was applied the day after pollination. Series 4, the check, received no sulfur. From these results, it is clear that if sulfur is present on the stigma before the pollen grain has had time to germinate and penetrate the style, fertilization does not take place. In most cases sulfur applied 24 hours after pollination greatly reduced the set. If, however, pollination and fertilization have already been accomplished, the sulfur would probably have no effect, as shown by the fact that blossoms dusted at the end of bloom set satisfactorily (table 4). The length of time required for the pollen grains to germinate and for the pollen tube to penetrate the style for a distance sufficient to escape injury by the sulfur would vary with the variety of pollen, some pollens germinating quickly and growing more rapidly than others, and with the temperature, the rate of pollen-tube growth being slower at lower temperatures.

The time required for the pollen tube to traverse the length of the style to the ovary of the apple has been determined experimentally by different workers. Sandsten (1909) found that in artificial media apple-pollen tubes made growth equivalent to the average length of the style in 32

TABLE 2. RESULTS FROM THE APPLICATION OF POLLEN AND DUSTING-SULFUR TO APPLE BLOSSOMS ON VIGOROUS SPURS, SPRING, 1929*

Treatment	Tree number	Variety	Number of spurs treated†	Number of flowers setting fruit, June 15		Number of flowers setting fruit, July 20		Per cent of flowers setting fruit, July 20	
				Pollen only applied	Pollen and sulfur applied	Pollen only applied	Pollen and sulfur applied	Pollen only applied	Pollen and sulfur applied
1. Pollen and sulfur applied at the same time	1	McIntosh.....	11	5	1	4	1	36.3	9.0
	2	Northern Spy.....	11	10	0	0	0	81.8	0.0
	3	Early Strawberry.....	16	3	0	2	0	12.5	0.0
	4	Hubbardston.....	26	2	0	2	0	7.6	0.0
	5	Rome.....	28	24	6	19	1	67.8	3.5
	6	Northern Spy.....	21	17	2	16	1	76.1	4.7
Average.....				10.2	1.5	8.7	0.5	47.0	2.9
2. Sulfur applied 24 hours before the pollen	1	McIntosh.....	10	5	0	5	0	50.0	0.0
	2	Northern Spy.....	10	10	1	10	0	100.0	0.0
	3	Early Strawberry.....	24	4	1	2	0	8.3	0.0
	4	Hubbardston.....	23	5	0	5	0	21.7	0.0
	5	Rome.....	19	17	1	14	0	73.0	0.0
	6	Northern Spy.....	19	14	0	13	0	68.4	0.0
Average.....				9.2	0.5	8.2	0	53.7	0.0
3. Sulfur applied 24 hours after the pollen	1	McIntosh.....	10	2	4	3	4	30.0	40.0
	2	Northern Spy.....	9	4	1	3	0	33.3	0.0
	3	Early Strawberry.....	11	2	0	1	0	9.0	0.0
	4	Hubbardston.....	26	4	0	3	0	11.5	0.0
	5	Rome.....	18	16	3	16	2	88.8	11.1
	6	Northern Spy.....	26	16	4	8	0	30.7	0.6
Average.....				7.3	2.0	5.7	1.0	33.9	8.5
4. Pollen only applied	1	McIntosh.....	12	7		7		29.2	
	2	Northern Spy.....	9	9		9		50.0	
	3	Early Strawberry†.....	8	0		0		0.0	
	4	Hubbardston.....	18	0		0		0.0	
	5	Rome.....	20	20		15		37.5	
	6	Northern Spy.....	23	15		7		15.4	
Average.....				8.5		6.3		21.9	

* Flowers were thinned to two on each spur and were covered with glassine bags. Pollen and sulfur were applied with a small brush.

† On each spur in treatments 1, 2, and 3 both flowers were pollinated but only one received sulfur.

‡ Not pollinated.

hours. In the field, however, fertilization did not take place until from 48 to 60 hours had passed. Cooper (1929) found pollen tubes in the micropyle of apple ovules 24 hours after pollination, and Knight (1918) states that the pollen tube of Jonathan traversed the length of a Rome Beauty style in 48 hours. It is impossible to say at present how far from the stigma a pollen tube must have grown to be safe from injury from sulfur on the stigma. It is reasonable to suppose, however, that even before fertilization takes place sulfur would have little effect. Taking 48 hours as the interval necessary between pollination and fertilization under favorable conditions of temperature, it is probable that dusting after this interval would not be detrimental, a supposition which accords with the evidence obtained from dusting just before the petal-fall when the early blooming season was favorable for pollination.

In table 3 are given the results of another experiment in which blossoming branches about one inch in diameter were enclosed in cheesecloth bags, about 3 feet by 6 feet, to protect them from insect visits. The treatment of the different branches was similar to that given the selected spurs (table 2). At the time of dust application all unopened flowers were removed, so that all flowers remaining on the tree were treated. The results in this case were the same as those obtained on the hand-pollinated spurs in that sulfur on the stigmas before or shortly after pollination prevented the fruit from setting. It is evident that sulfur applied the day

TABLE 3. RESULTS FROM THE APPLICATION OF POLLEN AND DUSTING-SULFUR TO APPLE BLOSSOMS IN FULL BLOOM, SPRING, 1929*

Treatment	Tree number	Variety	Circumference of branches (centimeters)	Number of blossom clusters	Per cent of growing points blossoming†	Number of clusters with fruit, July 19	Per cent of blossom clusters with fruit, July 19
1. Pollen and sulfur applied at the same time	1	Rome.....	10.8	89	64.0	1	1.1
	2	McIntosh...	7.1	60	69.0	3	5.0
2. Pollen applied 24 hours after the sulfur	1	Rome.....	8.5	95	76.0	0	0.0
	2	McIntosh...	8.5	66	54.1	12	18.1
3. Pollen applied 24 hours before the sulfur	1	Rome.....	5.4+6.2	67	64.4	5	7.4
	2	McIntosh...	7.5	85	76.6	17	20.0
4. Pollen only applied	1	Rome.....	6.5+6.0	94	77.7	26	27.6
	2	McIntosh...	7.4	85	68.0	34	40.0

* The selected branches were enclosed in cheesecloth bags to protect them from insect visits. The pollen was applied with a brush and the dust was applied with a hand duster.

† The number of growing points includes the growths from lateral buds on vegetative shoots as well as those from the spurs.

following pollination reduced the set but not so much as did the earlier dust applications. The larger set of fruit on McIntosh as compared with Rome might be explained on the basis of more rapid growth of pollen tubes in the interval between pollination and dust application, due to higher temperatures or to better pollen.

Another series of experiments is reported in table 4. From 6 to 8 limbs about one inch in diameter were selected for equal vigor on each of six trees. One of the limbs on each tree was dusted on successive days

Northern Spy AE 4.....	I	10.7	124	46.6	56	45.2	37	29.8	17	Terminal and few lateral flowers open
	2	9.7	117	59.9	36	39.8	24	29.5	18	Terminal and $\frac{1}{2}$ lateral flowers open
	3	10.4	40	24.9	8	16.3	6	12.2	19	Terminal and $\frac{1}{4}$ lateral flowers open
	4	8.8	33	22.1	11	33.3	11	33.3	20	Most flowers open
	5	11.2	142	59.9	70	49.3	40	28.2	.....	Check, no dust applied
	6	8.5	55	47.0	28	59.9	14	25.5	.....	Check, no dust applied
Average, check.....										
Northern Spy AG 2.....	I	9.2	126	73.3	62	49.2	21	16.7	18	Terminal flowers open, laterals in balloon stage
	2	6.2(A) 9.0(B)	181	85.8	66	36.5	36	19.9	19	Terminal and very few lateral flowers open
	3	9.5	128	65.6	24	18.8	17	13.3	20	Terminal and $\frac{1}{2}$ lateral flowers open
	4	9.2	126	68.9	37	29.4	27	21.4	21	Terminal and $\frac{1}{4}$ lateral flowers open
	5	10.5	116	65.2	20	17.2	20	17.2	23	All flowers open
	6	10.6	150	66.9	87	58.0	49	32.7	.....	Check, no dust applied
Average, check.....										
Rhode Island Greening AH 3.....	I	12.5	196	58.0	30	15.3	22	11.2	18	Terminal flowers open, laterals in balloon stage
	2	13.2	189	86.7	84	44.4	53	28.0	19	All flowers open
	3	5.7(A) 8.7(B)	113	38.2	51	45.1	43	38.1	20	All terminal flowers open, most laterals in balloon stage
	4	9.6	140	83.8	27	19.3	18	12.0	21	All flowers open
	5	7.5	162	65.4	13	12.7	8	7.8	23	Petals just beginning to fall
	7	8.0	73	.....	30	41.1	20	19.6	.....	Check, no dust applied
Average, check.....										
Average, check.....	8	6.5	61	.....	26	42.6	18	29.5	.....	Check, no dust applied
	.....	.....	.....	.....	.....	.....	.....	28.5	.....	Check, no dust applied
										
										
										
										

* The number of growing points includes the growth from lateral buds on long shoots as well as that from the spurs.

TABLE 5. RESULTS FROM THE APPLICATION OF DUSTING-SULFUR TO ENTIRE TREES WHILE IN BLOOM, OPEN POLLINATION, SPRING, 1920*

Tree number and treatment	Branch number	Circumference of branch (centimeters)	Number of flower clusters	Per cent of growing points blossoming	June 15		July 20			Condition of flowers when dusted
					Number of flower clusters	Per cent of flower clusters set	Number of flower clusters set	Per cent of flower clusters set	Date dusted	
Northern Spy										
NA 16 (whole tree dusted each day)	1	9.0	65	31.4	11	16.9	8	12.3	May 17	Terminal and some lateral flowers open on May 17; all flowers open on May 23; petals beginning to fall on May 25
	2	11.2	60	18.4	6	10.0	6	10.0	to	
	3	12.0	208	59.1	40	19.2	40	19.2	May 25	
Average, dusted								13.5		
Northern Spy										
NC 14	1	10.3	95		43	45.3	30	31.6		Check, no dust applied Check, no dust applied Check, no dust applied Check, no dust applied Check, no dust applied Check, no dust applied
	2	10.5	43	.....	25	58.1	14	32.6	.....	
	3	9.0	96	35.6	.....	.....	60	62.5	.....	
	4	7.5	34	42.9	.....	.....	19	55.8	.....	
	5	9.0	37	15.5	.....	.....	23	62.1	.....	
Average, check	6	9.0	95	36.2	.....	.....	40	42.1	.....	
Wealthy										
KL 4 (whole tree dusted once)	1	9.8	133	72.2	120	90.2	65	48.9	May 18	Tree in full bloom; some vigorous spurs not open; bees working actively
	2	7.5	136	76.8	100	77.9	22	16.2	May 18	
	3	18.5	136	83.8	117	74.1	88	55.7	May 18	
Average	4	8.3	87	60.8	71	81.6	40	46.0	May 18	
Wealthy										
KL 8 (whole tree dusted once)	1	7.6	141	92.1	115	81.6	28	19.9	June 1	Petals just beginning to fall
	2	7.1	90	90.0	79	87.8	22	24.4	June 1	
Average	2	7.0	110	77.4	94	85.5	37	33.6	June 1	

* Dust was applied with a hand duster. Counts were on representative branches.

from the time the terminal buds only were open until the petals fell, each limb being dusted only once. The set of fruit on many of the dusted branches would be sufficient for a commercial crop. However, on all trees the average set of fruit on the check limbs receiving no dust was greater than that on the limbs that were dusted, the amount of reduction probably depending upon the proportion of unpollinated or recently pollinated flowers, the stigmas of which received sulfur and, therefore, were not receptive to subsequent pollination. As each limb was dusted only once, there would always be many blossoms unopened at the time of dust application on the limbs dusted in the early blooming season. When dusting was done late in the blooming period, there were blossoms that had already been pollinated for a sufficient time to be uninjured. Conditions for pollination were good during the blooming season of these trees.

The results obtained where whole trees were dusted are given in table 5. On Wealthy trees dusted once while in full bloom there is obviously a heavy set of fruit, for twenty fruits on unit limbs of this size are sufficient for a commercial crop. On the Northern Spy tree dusted on nine successive days there is a marked reduction in the crop, in comparison with the check tree. Considering the two trees as a whole the one dusted daily did not set a commercial crop whereas the set on the check was heavy.

In a McIntosh orchard where the set of fruit was very light because of lack of pollination, a single application of dust during full bloom reduced the set on selected limbs, as shown in table 6. The set of fruit on the check limbs was insufficient for a full crop but was much better than on the dusted branches. The number of limbs involved is probably too small to be conclusive, but as the results accord with the other data they may be regarded as additional evidence on the effect of dust in reducing the set of fruit. Such a reduction in crop would be a significant loss to the grower under these circumstances.

TABLE 6. EFFECT OF DUSTING WITH SULFUR DURING BLOOM IN A MCINTOSH ORCHARD WHERE THE SET OF FRUIT WAS LIGHT BECAUSE OF THE LACK OF ADEQUATE INSECT POLLINATION, SPRING, 1929

Treatment	Branch number	Circumference of branch (centimeters)	Number of flower clusters	Per cent of growing points blossoming	Number of clusters with fruit, July 20	Per cent of blossoming spurs with fruit
Checks, no dust.....	1	6.4	82	80.4	9	10.9
	2	7.8	84	67.2	8	9.5
Average.....						10.2
Dusted once in full bloom	3	8.5	92	80.0	4	4.3
	4	6.5	83	63.4	0	0.0
Average.....						2.2

DISCUSSION

From the foregoing data it is apparent that under certain conditions sulfur dust lodging on the stigmas of apple blossoms will prevent pollen germination and will reduce or prevent the setting of fruit. In order to be injurious, however, the sulfur must be on the stigmas before fertilization has taken place, or at least before the pollen tube has entered the style a sufficient distance to be out of reach of the sulfur. The practical

effect of dusting during bloom, therefore, may or may not be a reduction of the set of fruit, depending on the time of dust application with reference to pollination. When there is little or no favorable weather for pollination in the early part of the season, an application of sulfur while the trees are in blossom might seriously reduce the yield by preventing the effective action of subsequent pollination. In regions where poor conditions for pollination frequently occur, particular caution should be used in dusting in bloom. On the other hand, if there has been favorable weather for pollination during the first part of the blooming period, it is doubtful if there would be any detrimental effect from dusting with sulfur just before the petals fall or 48 hours after a period of favorable conditions for pollination, provided the temperature during the interval had not been too cold for normal pollen-tube growth. In fact, the application of sulfur dust during the later stages of bloom might, on theoretical grounds at least, actually increase the set of fruit by reducing the conditions of competition between flowers on the same spur, which lead to a heavy June drop. Such an effect is suggested by the data on the variety Hubbardston in table 2, where it is shown that on the check spurs that received pollen only on both flowers on the spur the set of fruit was less than on those where one of the two blossoms was brushed with sulfur and further development was prevented. The percentage of blossoms setting with pollen only on the check spurs of all trees reported in this table, was less than on the spurs where one blossom was eliminated by the sulfur. Howlett (1929) has shown that a larger number of Delicious spurs will hold fruit if the blossoms are thinned to one or two per spur than if all the flowers are allowed to remain.

The advisability of applying sulfur dust to apple blossoms would also depend upon the variety concerned. With sorts that characteristically set a light crop with only one fruit to a spur, as for example McIntosh, Delicious, and Greening, reducing the set of fruit by dusting during the bloom would be more serious from a commercial standpoint than with such varieties as Wealthy, Baldwin, and Wagener, which usually set several fruits to a cluster and require thinning for best results.

The considerations brought out in the preceding paragraphs have to do entirely with the effect of sulfur on pollen germination and fruit setting and have nothing to do with the necessity or expediency of spraying or dusting during bloom, or with the effect of these practices upon bees and other agents of pollen transfer.

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